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POWER REQUIREMENTS FOR HIGH-CAPACITY COTTON GINS
IN THE YAZOO-MISSISSIPPI DELTA

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INTRODUCTION

The unrestricted production of cotton during World War II and the attendant farm labor shortage dramatized the need for mechanical harvesters to harvest the U.S. cotton crop. Ginning tests on cotton harvested by experimental models of mechanical harvesters showed that mechanically picked cotton processed in the ginning plants of that day averaged two grades lower than cotton handpicked from the same field.

Immediately following the War, the U.S. Cotton Ginning Research Laboratory at Stoneville, Miss., developed a lint-cleaning device that greatly narrowed the grade gap between hand-picked and machine-picked cotton. Other tests showed that additional seed-cotton-cleaning machinery in combination with adequate drying was also highly beneficial in removing foreign matter from mechanically harvested cotton.

More recently, the harvesting rate has increased to such a point that increased ginning rates are considered necessary to keep a reasonable pace with harvesting. Consequently, today's cotton gins necessarily contain more machinery and represent much greater capital investments than such plants of the World War II period.

As gins have grown in complexity and size, power requirements have increased. One of the recent trends in gin engineering is the powering of each machine or machinery group with its separate electric motor. This power scheme permits the plant to continue production even though a temporary stoppage has part of the plant out of production. A second trend in gin design is that of providing split-stream handling of seed cotton in the larger plants.

Because of the many different mechanical options for processing cotton in gin plants, the need has arisen for reevaluating power requirements for the ginning processes to determine the most suitable plant layout and machinery complements for optimum use of power in cotton gins.

This is a progress report on power requirements, energy consumption, and costs of high-capacity, all-electric cotton gins in the Mississippi River Valley (Yazoo-Mississippi Delta) based on work done during the 1962-63 crop year.

METHODOLOGY

Detailed power data were collected from six all-electric gins in Louisiana and Mississippi during the 1962 ginning season. Gins were selected so that major gin companies would be represented. To facilitate data collection and interpretation of results, gins were selected with an individual motor drive on each piece of machinery. Volts, amperes, and power factors were read at individual motor starter boxes by use of a voltmeter, ammeter, and power-factor meter. Horsepower input for each motor was calculated by using the conventional relationship:

$$Hp_{3\phi} = (\sqrt{3})\ (E)(I)\ (P.F.)/746$$

Where E   = Voltage
       I   = Amperes
      P.F. = Power factor
      $\sqrt{3}$ = 1.73
      746 = Watts per horsepower

Power supply for all six gins was 440 volts, 3-phase, Delta connected.

Three sets of readings were taken on each machine (or connected unit) during the ginning season--one while the machine was running idle, and two while cotton was passing through the machine at approximately the rated capacity, the two latter readings being averaged.

Per bale energy consumption for each plant was measured by taking weekly readings at the power company's kilowatt-hour meter and dividing the quantity of kilowatt-hours used by the number of bales ginned each week as determined from the gin books. Seasonal energy consumption per bale was established in a similar manner by use of seasonal totals.

Tests were conducted during the 1962 ginning season to determine the effect of ginning rate on power requirements for gin stands, extractor feeders, and lint cleaners. Power measurements were made by connecting a recording wattmeter to each motor circuit at the starter box. Four one-bale lots of cotton were processed through each machine at different feed rates; ginning rates were established by timing each bale with a stopwatch. Curves were then plotted and mathematical equations derived to illustrate variation in power requirements with ginning rate for each machine.

TEST RESULTS

Power requirements and energy consumption for the entire ginning operation have an important effect on costs of ginning. An analysis of these items for the different phases of ginning could provide clues to possible savings. Studies into the relationships between power requirements and energy consumption on the one hand, and the rate of ginning on the other, provide information on the importance of keeping an even flow of cotton through the system in quantity sufficient to maintain production of the stands at near-optimum levels.

Total Power Requirements, Energy Consumption, and Costs

Range in connected horsepower was from 624.5 to 917.0 hp., with an average of 764.5 hp. (table 1). Total operating load, or power input to the motors required while plants were ginning, averaged 609.4 hp., with the highest operating load being 776.3 hp. and the lowest 510.1 hp. Average operating load was approximately 80 percent of average connected load.

Power requirements for operating the various gins while running idle ranged from 347.2 to 654.9 hp. and averaged 479.5 hp. Difference in the power requirements while running idle and while ginning averaged 130.2 hp., indicating that only 21 percent more power is required for ginning cotton over that required for running the plant idle.

Fans, both centrifugal and axial type, represent the largest power-consuming element within a gin plant. Fans accounted for an average of 52.1, 57.7, and 77.7 percent of the total connected, ginning, and idling loads, respectively (table 2). Idling load for fans was approximately 6 percent greater than ginning load. This illustrates that unthrottled fans require less power when handling a mixture of air and solid material than when handling air alone.

Table 1. Ginning capacity and selected power data for 6 high-capacity gin plants, 1962

| Item | Gin identification | | | | | | |
---	A	B	C	D	E	F	Avg.
Plant capacity--------bales per hr---	11.7	12.2	10.5	9.8	8.9	9.7	10.5
Connected load-------------------hp---	844.5	917.0	762.0	689.5	749.5	624.5	764.5
Connected load, capacity hp. per bale per hr---	71.8	75.4	72.6	70.2	84.5	64.6	73.2
Energy consumption----kw.-hr. per bale---	52.2	46.7	43.8	48.7	48.2	45.5	47.5
Operating load, ginning------------hp---	776.3	645.8	604.4	603.3	510.1	516.7	609.4
Operating load, capacity hp. per bale per hr---	65.0	53.2	57.5	61.4	57.7	53.3	58.0
Idle load--------------------------hp---	654.9	547.4	459.6	431.4	436.3	347.2	479.5
Operating load minus idle load------hp---	112.5	98.4	144.8	171.9	83.8	169.5	130.2

Table 2. Fan power requirements: Fan loads as a proportion of specified total-power requirements for 6 high-capacity gins, 1962

Gin identifi-fication	Horsepower requirements								
	Connected			Ginning			Idling		
	Total	Fan	Fan propor-tion	Total	Fan	Fan propor-tion	Total	Fan	Fan propor-tion
	Hp.	Hp.	Pct.	Hp.	Hp.	Pct.	Hp.	Hp.	Pct.
A--------	844.0	482.5	57.1	767.4	499.0	65.0	654.9	515.0	78.6
B--------	917.0	445.0	48.5	645.8	351.9	54.5	547.4	404.1	73.8
C--------	762.0	420.0	55.1	604.4	381.9	63.2	459.6	394.2	85.8
D--------	689.5	367.5	53.3	603.3	329.1	54.5	431.4	351.6	81.5
E--------	749.5	437.5	58.3	510.1	312.1	61.2	436.3	349.7	80.2
F--------	624.5	235.0	37.6	516.7	229.5	44.4	347.2	221.4	63.8
Avg.--	764.4	397.9	52.1	608.0	350.6	57.7	479.5	372.7	77.7

There is little difference between average kilowatt-hour requirements per bale ginned on the high-capacity plants and conventional gins. The high-capacity gin plants, using only electric power, consumed an average of 47.5 kw. -hr. per bale ginned. A power survey of 90 all-electric, conventional, 12-inch saw gins, ranging in size from simple 3-80 plants to elaborate 5-90 plants, showed an average energy consumption of 46.1 hw. -hr. per bale ginned.[3] Energy consumption per bale ranged from 44 to 52 hw. -hr. for the high-capacity gin plants and 28 to 72 kw. -hr. for conventional gins.

3/ Holder, S. H., and McCaskill, O. L. Costs of Electric Power and Fuel for Driers in Cotton Gins, Arkansas and Missouri. U.S. Dept. Agr., Econ. Res. Serv. ERS-138, 12 pp. 1963.

The average cost for electric energy during the 1962 ginning season was 3.3 cents per kw. -hr., based on a survey of 33 all-electric gin plants in the Yazoo-Mississippi Delta. Applying this average cost to per bale kw. -hr. consumption, energy cost for the six gins studied ranged from $1.44 to $1.72 per bale, averaging $1.57 per bale. Energy costs for conventional 12-inch saw gins, based on the rate of 3.3 cents per kw. -hr., ranged from $0.92 to $2.38 per bale and averaged $1.52 per bale.

The almost identical energy consumption per bale by these two types of gins occurs as a result of (1) lower power requirements but greater ginning time per bale for conventional gins, and (2) increased power requirements but decreased ginning time for high-capacity gins. For example, a conventional gin, operating at a rate of six bales per hour, with an operating load of 400 hp., or 300 kw., would use 50 kw. -hr. of energy for each bale ginned. This same 50 kw. -hr. of energy would be required for a high-capacity gin with an operating load of 800 hp., or 600 kw., ginning at the rate of 12 bales per hour.

Plant capacity for the six gins ranged from 8.9 to 12.2 bales per hour, with an average of 10.5 bales per hour, based on the time that the gin stands were actually ginning cotton (table 1).

Power Requirements, Energy Consumption, and Costs, by Major Ginning Functions

To provide a more detailed breakdown of power requirements, energy consumption, and costs, the ginning operation was divided into six major functions--materials handling, drying, seed cotton cleaning, ginning, lint cleaning, and tramping and pressing (table 3). A power analysis of this type points up those areas with greatest potential for power savings.

Materials Handling
From the standpoint of power requirements, materials handling is primarily a function of the pneumatic system. From the seed cotton entering the unloading telescope to the trash blown to the burner (or burr pile), materials are moved mainly by air.

Seed Cotton
The seed cotton conveying system consists of the unloading fan, automatic feed control, distributor and overflow fan, and separator. Power requirements for the seed cotton system ranged from 55.0 to 136.4 hp. and averaged 79.5 hp. for the six gins (table 3). Wide variations in power requirements for handling seed cotton may be accounted for by number and size of fans in the unloading system, for the number and size are somewhat dependent on the ginning capacity of the plant. The gin requiring 136.4 hp.

to handle seed cotton had an unloading system consisting of two size 45 fans in series. These two fans accounted for more than 100 of the 136.4 hp. required for the seed-cotton-handling system. Energy consumption for seed cotton handling averaged 6.2 kw.-hr. per bale, with an average per bale cost of 21 cents.

Table 3. Average power requirements, energy consumption, and energy cost, by ginning function, for 6 high-capacity gin plants, 1962

Ginning function	Power requirement			Energy consumption per bale	Energy cost per bale[1]
	Low	High	Avg.		
	Hp.	Hp.	Hp.	Kw.-hr.	Dollar
Materials handling:					
Seed cotton--------------	55.0	136.4	79.5	6.2	0.21
Cottonseed---------------	10.1	37.4	15.9	1.2	.04
Lint[2]------------------	------	------	------	----------	---------
Trash--------------------	[3]0.0	127.2	58.2	4.5	.15
Total------------------	-----	------	153.6	11.9	0.40
Other functions:					
Drying------------------	112.4	189.3	140.5	11.0	0.36
Seed cotton cleaning-----	19.7	57.4	33.1	2.6	.09
Ginning------------------	58.1	130.6	109.4	8.5	.28
Lint cleaning-----------	81.4	121.1	99.0	7.7	.25
Tramping and pressing----	55.3	98.1	74.0	5.8	.19
Grand total------------	-----	------	609.6	47.5	1.57

1/ Based on an average energy rate of 3.3¢ per kw.-hr., from a survey of 33 all-electric gins in the Yazoo-Mississippi Delta area, 1962.

2/ Lint conveyed by means of the gin stand and its lint-cleaner doffing system and exhaust fans and charged to cost of ginning and lint cleaning.

3/ In 2 instances, trash handled by drier fans or by both drier fans and fans powered by lint-cleaner motor.

Cottonseed

Two systems are presently employed in high-capacity gins for conveying cottonseed. One system utilizes a centrifugal-type fan and large piping, ranging in size from 10 to 14 inches in diameter. The other system consists of a positive-displacement-type blower and small pipe, ranging from 4 to 6 inches in diameter. It is the difference in power requirements between these two systems which accounts for wide variations in power requirements for seed handling. Small-pipe systems require approximately one-third as much power as systems using centrifugal fans and large pipe.

Of the six gins studied, one utilized a large-pipe system for seed handling and five used a small-pipe system. Power requirements were 37.4 hp. for the one large-pipe system; for the small-pipe systems they ranged from 10.1 to 13.7 hp., with an average of 11.6 hp. Thus, considerable power savings may be obtained with the use of small-pipe systems.[4/] Energy consumption for seed handling in the six gins averaged 1.2 kw.-hr. per bale at an average cost of 4 cents per bale.

Lint

For the purpose of this analysis, no power requirements were allotted to lint conveying, since lint is moved from one point to another by the gin stand and its lint-cleaner doffing system and exhaust fans. Power-consumption and cost figures for handling lint are included with the ginning and lint-cleaning figures of table 3.

Trash

There were wide variations in power requirements for handling trash. These variations may be accounted for by the amount of trash removed by drier fans and ginning capacity of the various plants. In two gins, a mote fan, powered by the lint-cleaner motor, handled lint-cleaner trash; this power is included as a part of the lint-cleaning process, since a separate measure of power required by the mote fan could not be made using the methods employed in this study.

For the gins in which no power was specifically assigned to handling of trash, drier fans, and in some cases fans powered by lint-cleaner motors, were employed to accomplish this function; therefore, the amount of power required to move trash could not be measured. Accordingly, power requirements for trash handling varied from 0 to 127.2 hp., with an average of 58.2 hp. Energy consumption for trash handling averaged 4.5 kw.-hr. per bale at an average cost of 15 cents per bale.

[4/] Bennett, C. A. and Franks, G. N. Cottonseed Handling With Small Air Pipes, U.S. Dept. of Agr. Cir. 768, rev., 8 pp 1953.

Total-power requirement for the materials-handling function averaged 153.6 hp. This represents approximately 25 percent of the total-power requirements for operating a high-capacity gin plant. Test observations and analysis of data for this study indicate three possibilities for reducing power requirements for materials handling: (1) Full utilization of drier fans for handling trash, (2) use of small-pipe systems for conveying seed and trash,[5] and (3) more efficient use of air supplied by unloading fan by use of a properly operated automatic-feed-control unit.

Energy consumption for materials handling averaged 11.9 kw.-hr. per bale, at a cost of 40 cents per bale.

Drying

Drying systems for gins covered in this study consisted of shelf-type tower driers and necessary fans for conveying cotton and hot air through the towers. Ginning capacity and plant layout are the major factors accounting for variations in power requirements for drying among the six gins. Power requirements for operating drier fans ranged from 112.4 to 189.3 hp. The average power requirement was 140.5 hp., or 23.2 percent of the total power requirements. In all cases, drier pull fans were also utilized for trash conveying (figures for which were not obtainable for inclusion with trash data of table 3). On the average, the drying systems accounted for 11.0 kw-hr. per bale energy consumption at a per bale cost of 36 cents.

Seed Cotton Cleaning

The seed cotton cleaning process constitutes the smallest power-consuming function within a high-capacity gin plant. This system comprises all the seed-cotton-cleaning machinery with exception of the extractor feeder, which is considered as part of the ginning function. Variations in power requirements among these gins may be accounted for mainly by the ginning capacity of the various plants, the number and kind of cleaners, and whether plant layout is split stream or single stream. Average power requirement for seed cotton cleaning was 33.1 hp., or 5.5 percent of the total power requirements, with a range from 19.7 to 57.4 hp. Per bale energy consumption averaged 2.6 kw.-hr. at a cost of 9 cents per bale.

Ginning

Power requirements for ginning are almost entirely dependent upon ginning rate. Other factors such as moisture content, variety, and trash content of cotton will slightly affect power requirements for fiber and seed separation.

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[5] Alberson, D. M., and Stedronsky, V. L. Gin Trash Handling With Small Air Pipe. U.S. Dept. Agr., Agr. Res. Serv. ARS 42-59, 7 pp. 1961.

Power requirements for ginning at approximate rated capacity ranged from 58.1 to 130.6 hp., averaging 109.4 hp. or 17.9 percent of the total power requirements for the six gins. Energy consumption for the fiber and seed separation process, which includes the energy for lint conveyance as part of the ginning process, averaged 8.5 kw.-hr. per bale at a per bale average cost of 28 cents.

Lint Cleaning

Power requirements, energy consumption, and cost for lint cleaning will vary according to number of stages of lint cleaning, ginning rate, and condition of cotton. Data for this function also include those for lint-cleaner exhaust fans. The six study gins had two stages of saw-type lint cleaning, and power measurements were made while plants were operating at approximately rated capacity. Power requirement for lint cleaning averaged 99.0 hp. (16.2 percent of the total power requirements), ranging from 81.4 to 121.1 hp. On the average, the lint-cleaning process consumed 7.7 kw.-hr. of electrical energy per bale at cost of 25 cents per bale.

Tramping and Pressing

The following machines are included in the tramping and pressing functions: Battery condenser, condenser exhaust fan, tramper and press. Power measurements were made while the press ram was at the end of the pressing stroke, i.e. while power requirements were at a maximum. Power requirements for this function ranged from 55.3 to 98.1 hp. An average of 74.0 hp. was required for tramping and pressing, accounting for 12.2 percent of the total power requirements. Per bale energy consumption averaged 5.8 kw.-hr. at a cost of 19 cents per bale. Values listed for power requirements, energy consumption, and cost are somewhat high because power measurements were made while the pressing load was maximum.

Effect of Ginning Rate on Power Requirements, Energy Consumption, and Cost for Various Gin Processes

Ginning rate has a very significant effect on power requirements for most machines used in the ginning process. Power requirements increase with increases in ginning rate for seed cotton cleaners, gin stands, and lint cleaners. Power requirements for fans decrease as materials handling rate is increased. This decrease becomes rather significant for drier and unloading fans, where large amounts of seed cotton are moved. Decrease in power requirements for trash and mote fans is smaller because increases in the solid materials conveyed are more limited.

Gin Stands

The power and energy studies for gin-stand operation were made by use of a 1962-model commercial gin stand with 16-inch-diameter saws rotating at 715 r.p.m.

The power required for fiber-seed separation increased exponentially as ginning rate increased (Fig. 1). The power required to increase the ginning rate from three to four bales per hour was nearly as much as that required to change it from zero to three bales per hour.
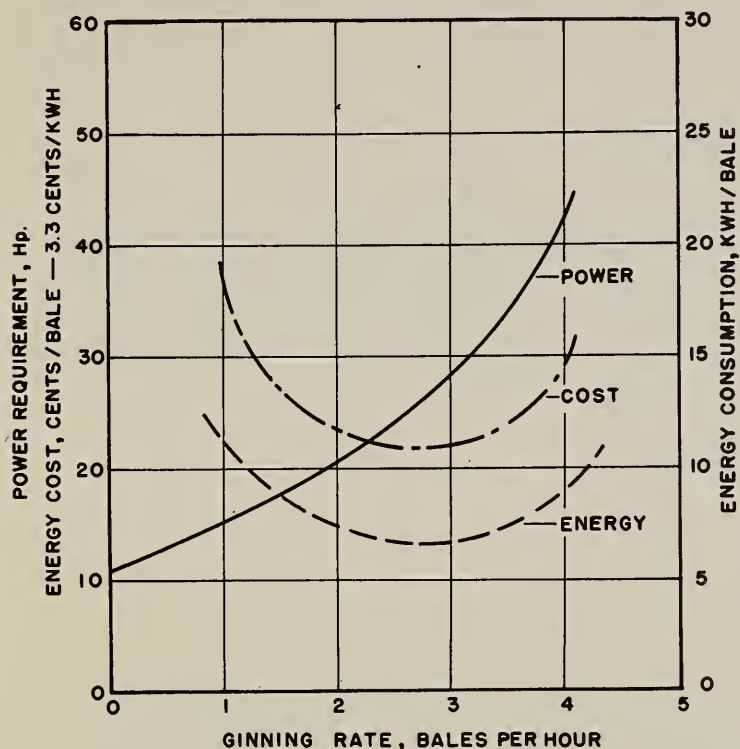
Energy consumption and energy cost were affected by both power requirements and ginning rate. The energy curves change from a high at low ginning rates to a minimum one at a higher rate, and then rise as ginning rate further increases. The most efficient use of electrical energy occurred at a ginning rate of approximately three bales per hour. Deviations above or below this rate will cause accompanying increases in per bale energy consumption and costs. Power requirements, energy consumption, and costs for fiber-seed separation will be slightly affected by variety and condition of cotton being processed.

Figure 1. Effect of ginning rate on power requirements, energy consumption, and cost for a typical high-capacity gin stand.

For a typical high-capacity gin stand, power requirements varied from 11.2 hp. while idling to 43.0 hp. while ginning at a rate of four bales per hour. Energy consumption varied from 11.2 kw.-hr. per bale at one bale per hour to 9.0 kw.-hr. per bale at 4 bales per hour, with a minimum of approximately 6.5 kw.-hr. per bale at a ginning rate of three bales per hour. Energy cost per bale varied directly with energy consumption, and ranged from 37 cents at one bale per hour to 29.5 cents at four bales per hour, with a minimum of 21 cents at three bales per hour. (Cost figures are based on a rate of 3.3 cents per kw.-hr.)

Extractor Feeders
    Power requirements for a typical extractor feeder ranged from 4.1 hp. while the machine was idling to 7.7 hp. while it was handling cotton at the rate of four bales per hour (Fig. 2). Per bale energy consumption ranged from 3.5 kw.-hr. at one bale per hour to 1.4 kw.-hr. at four bales per hour which also represented the point of minimum energy consumption. Cost of energy per bale ranged from 11.5 cents at one bale per hour to 4.8 cents at four bales per hour.
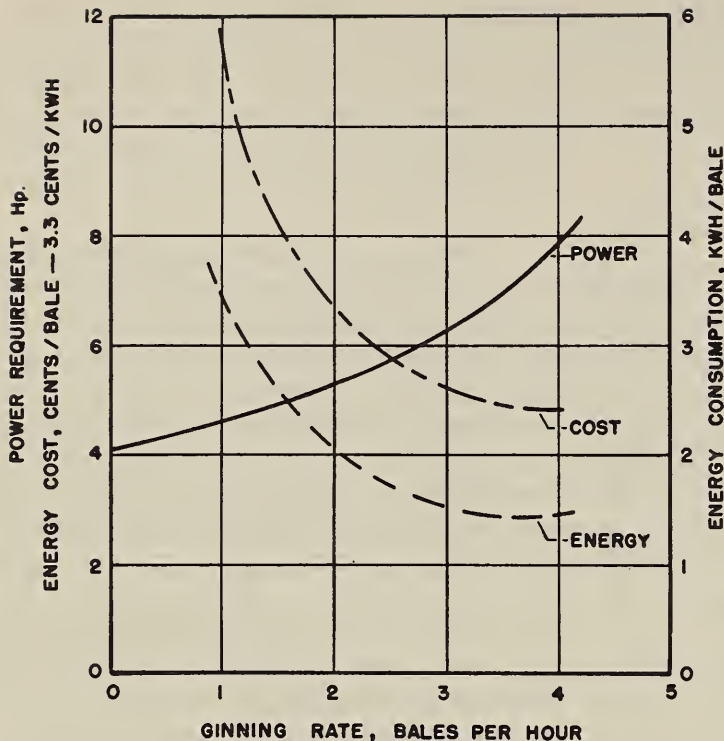
Figure 2. Effect of ginning rate on power requirements, energy consumption, and cost for a typical high-capacity extractor feeder.
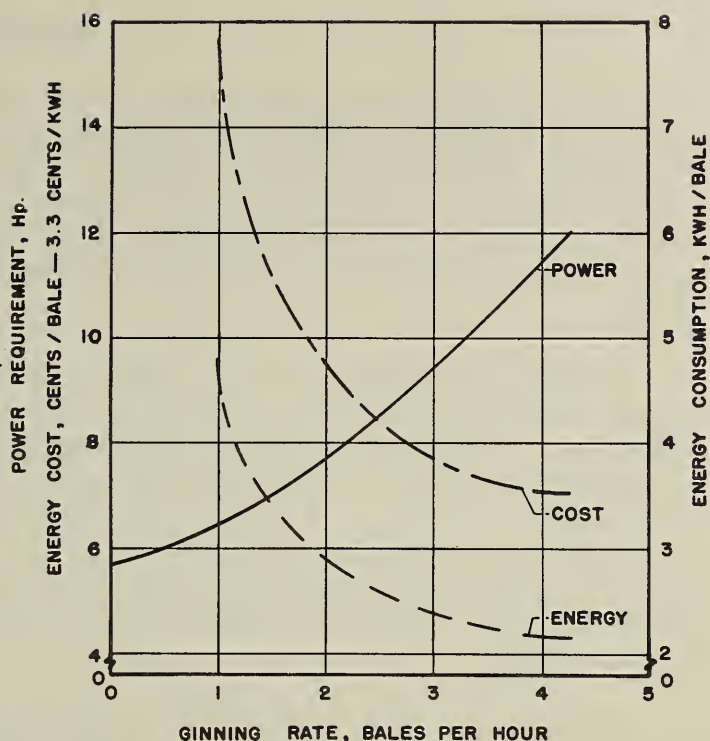
Lint Cleaners

Power requirements, energy consumption, and cost as influenced by ginning rate for high-capacity lint cleaners were obtained by using a 16-inch-diameter saw-type, brush-doffed cleaner. Saw speed was 875 r.p.m. Most of the power for lint cleaning, above idle-power requirement, may be accounted for by (1) feed rollers, which comb the lint between feed plate and saw cylinder, (2) and a whipping action of cotton over the grid bars. The power require-ments of the cleaner ranged from 5.7 while the machine was running idle to 11.4 while it was handling cotton at the rate of four bales per hour (Fig. 3).

Energy consumption ranged from 4.7 kw.-hr. per bale at one bale per hour to 2.2 kw.-hr. per bale at four bales per hour. Most efficient energy use occurred at a ginning rate of four bales per hour. Energy cost ranged from 15.3 cents per bale at one bale per hour to 7.1 cents per bale at four bales per hour.

RESULTS

Results of this study indicate that there is an optimum rate at which cotton may be processed through various gin machines, from the standpoint of energy requirements and costs. This optimum rate always occurs at the point where per bale energy consumption is a minimum.

Figure 3. Effect of ginning rate on power requirements, energy consumption, and cost for a typical high-capacity lint cleaner.

To make most efficient use of energy for gin stands, extractor feeders, and lint cleaners such as were included in this study, the machines must be operated at a ginning rate from three to four bales per hour. Deviations above or below these optimum rates tend to increase per bale energy requirements. Rapid increases in power requirements at higher rates account for increased energy consumption and cost per bale. At lower ginning rates, increased processing time per bale causes accompanying increases in energy consumption and cost.

Other factors which may influence power requirements, energy consumption, and cost are type, size, and condition of machinery used, and condition and variety of cotton processed.

Further studies are underway to determine the effect of ginning rate on power requirements, energy consumption, and cost for other gin machines. Field tests are also planned to obtain more detailed information on the average per bale power and energy requirements for pressing and tramping.

SUMMARY

Field tests were conducted during the 1962 ginning season to determine power requirements, energy consumption, and costs for operating high-capacity gin plants in the Yazoo-Mississippi Delta. Average capacity for the six gins studied was 10.5 bales per hour. Power requirements averaged 764.5, 609.4, and 479.5 hp. for the connected, operating, and idling loads, respectively. Per bale energy consumption averaged 47.5 kw.-hr.; per bale energy cost averaged $1.57.

Further analysis of these data was made to determine the power requirements, energy consumption, and cost for various functions within the ginning operation. The percentages of total energy consumption and costs were noted for these functions: Materials handling, 25.0 percent; drying, 23.2 percent; seed cotton cleaning, 5.5 percent; ginning, 17.9 percent; lint cleaning, 16.2 percent; tramping and pressing, 12.2 percent. Thus, it may be noted that the greatest potential for power savings is with the materials-handling and the drying systems, through more efficient use of air required to operate these systems.

Tests were also conducted to determine the effect of ginning rate on power requirements, energy consumption, and costs for these gin machines. The particular machines studied in this phase of work included a gin stand, a lint cleaner, and an extractor feeder. Power requirements increased exponentially with ginning rate for all three machines. Energy consumption and costs decreased with increased ginning rates for each machine, with the most efficient operation occurring at a rate from three to four bales per hour.